National Aeronautics and Space Administration

Human Exploration and Operations Committee Status

Ken Bowersox
Committee Chair
December 8, 2017

NAC HEO Committee Members

- Ms. Bartell, Shannon
- Mr. Bowersox, Ken, *Chair*
- Ms. Budden, Nancy Ann
- Ms. Caserta Gardner, Ruth G.
- Dr. Chiao, Leroy
- Dr Condon, Stephen "Pat"
- Mr. Cuzzupoli, Joseph W.
- Mr. Holloway, Tom
- Mr. Lon Levin
- Dr. Longenecker, David E.
- Mr. Lopez-Alegria, Michael
- Mr. Sieck, Robert
- Mr. Smith, Gerald
- Mr. Voss, James

NAC HEO Committee Meeting

Wednesday, November 7, 2017

- Human Exploration & Operations Status
- ISS Status
- Commercial Crew Program Status
- Exploration Systems Status

Thursday November 8, 2017

- Solar Electric Power Propulsion Element Status
- Advance Exploration System Status
- KSC Tour

ISS Increment 53 Overview: Crew

51S Dock 7/28/17
51S Undock 12/14/17

Sergei Ryazansky
Soyuz CDR (R) – 51S

Randy Bresnik
FE (US) – 51S
CDR Inc 53

Paolo Nespoli
FE (ASI) – 51S

52S Dock 9/13/17
52S Undock 2/26/18

Alexander Misurkin
Soyuz CDR (R) – 52S
(CDR Inc 54)

Joe Acaba
FE (US) – 52S

Mark Vande Hei
FE (US) – 52S

Increments 53 & 54

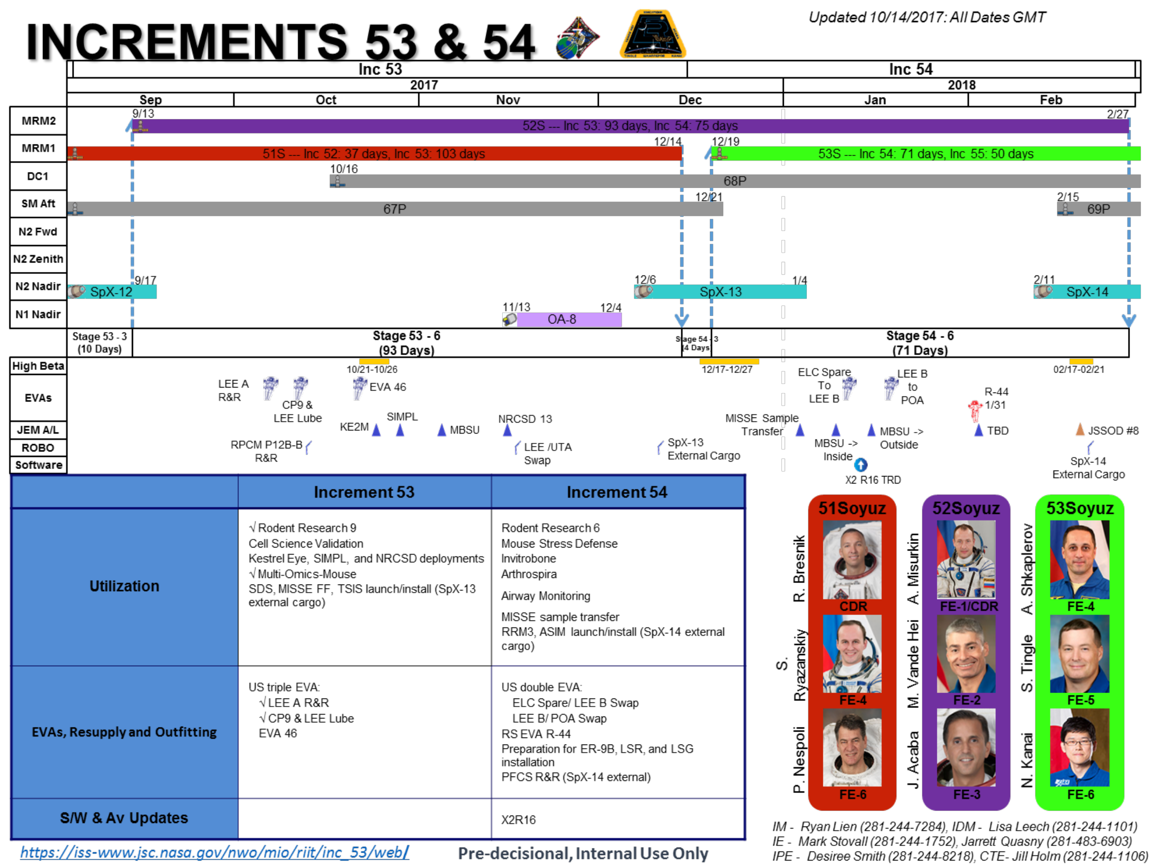
Increment 53: 103 days
- **Stage 53-3: 50S undock to 52S dock: 10 days**
- **Stage 53-6: 52S dock to 51S undock: 93 days**

– US Triple EVA Tasks
- » Remove degraded LEE A (s/n 202) from the SSRMS
- » Install LEE (s/n 203) on LEE A location
- » Install LEE (s/n 202) on POA
- » WIF Adapter Install on LEE A
- » Install EHDC CP3 ETVCG

– Cargo vehicles:
- » SpX-12 Unberth (9/17)
- » OA8 berth (11/13), release (12/3 TBC)
- » SpX-13 berth (12/6), release (1/4 TBC)

– Science/Utilization:
- » Rodent Research 9
- » SARCOLAB
- » Cell Science Validation
- » KABER deployments
- » NRCSD deployments
- » JSSOD deployments
- » SpX-13 (SDS, MISSE FF, TSIS)
- » Multi-Omics-Mouse

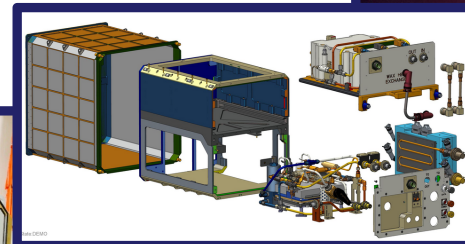
– Maintenance/Outfitting:
- » BEAM "Demo" and "Build Out" for Stowage
- » HTV-7 Rack Install Prep for the Life Support Rack, Water Storage System, and Life Sciences Glovebox
- » T2 Subject Loading System Installation

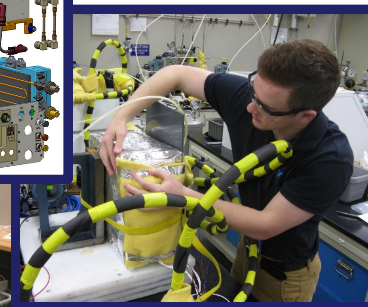


Phase Change Material Heat Exchanger (PCM HX) for Orion

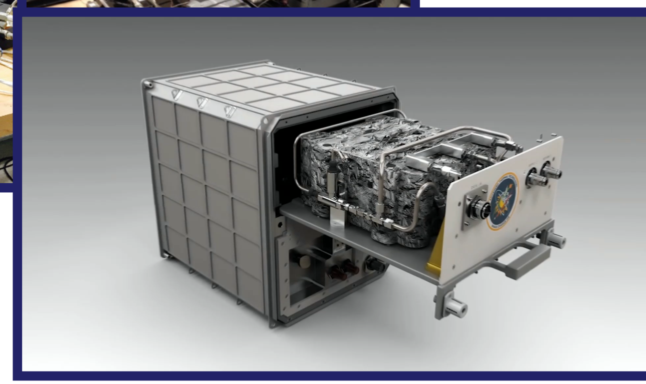
Microgravity Characterization Tests of Orion's PCM HX on ISS

Rubik Sheth, NASA Johnson Space Center





- Orion's radiators will not be sufficient for heat rejection during some exploration missions
- Phase Change Material Heat Exchangers have been baselined for use with risk associated to HX integrity during phase change
- Payload developed to test PCM HX on ISS
- Payload launched July 2016 and returned on SpX-12 in Sept 2017
- On-orbit characterization has proven the need for design modifications due to unexpected pressure increases within HX.



Comercial CrewProgram Summary

- **CCP continues to facilitate the development and certification of U.S. industry-based crew transportation systems**
- **Boeing and SpaceX are meeting contractual milestones and maturing their designs**
  - A significant amount of hardware is in development, test and qualification in preparation for upcoming missions
  - Risks are being identified and important design challenges are being addressed
  - NASA is engaged in meaningful insight
- **Both providers are making tangible progress toward flight tests and crewed missions to the International Space Station**
- **CCP has robust and efficient processes for certification including addressing waivers and deviations**
  - Progress is being made in the burn down of key certification products with the providers
- **In preparation for flight, there is significant work ahead**

Program Progress

CCP has made significant progress over the last quarter, notably:

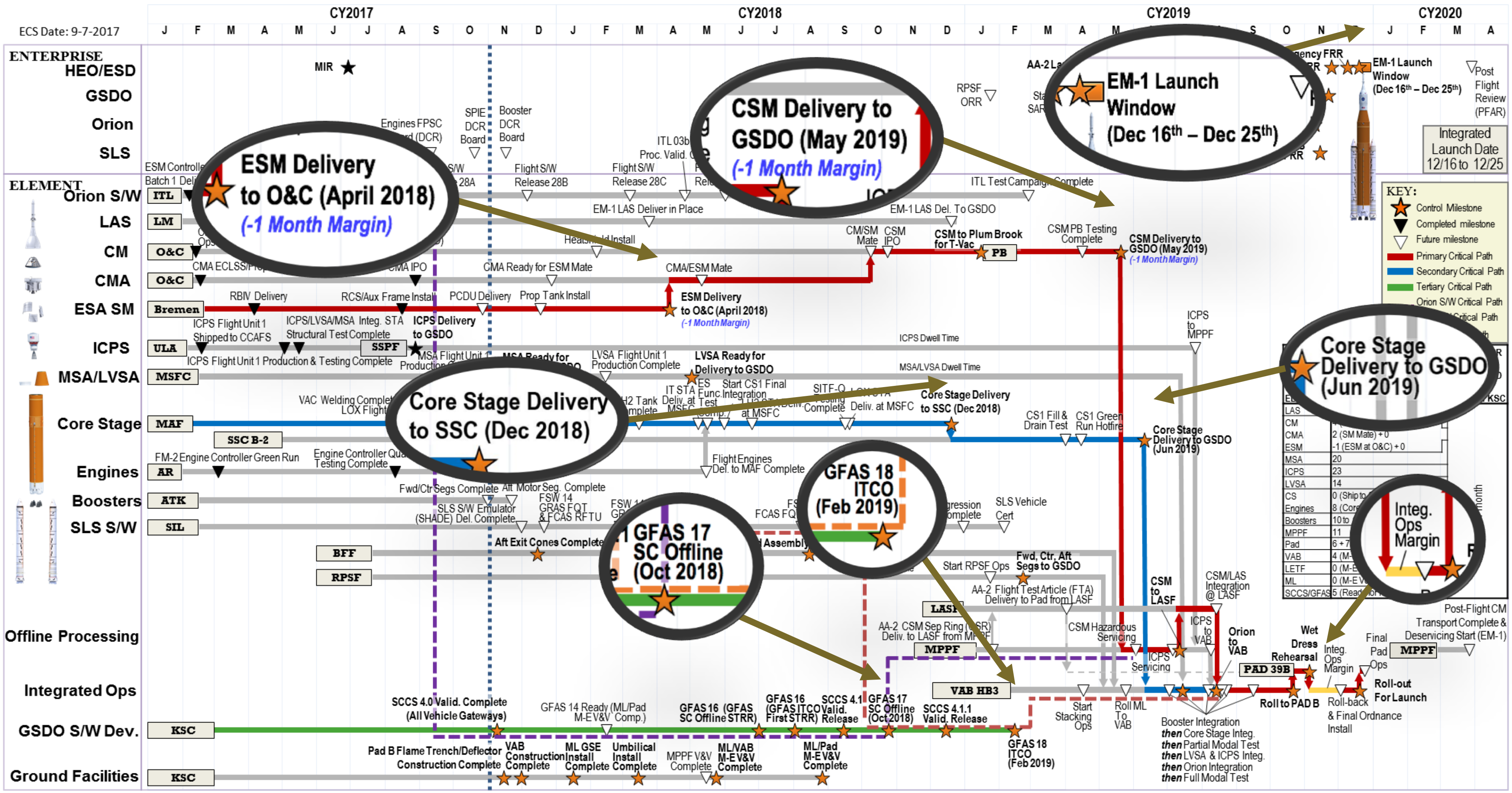
- **Program's Annual Review is complete**
  - Significant technical issues resolution and risk mitigations continue as CCP progresses toward flight tests and crewed missions to the International Space Station
  - Awarded Post Certification Missions (PCMs) 3-6 to both Providers
  - Multiple spacecraft and qualification test articles are in production and testing simultaneously
- **Mission planning and preparations for eight CCP missions are in work:**
  - Official Dates For Boeing:
    - August 2018: Orbital Flight Test (unmanned demo)
    - November 2018: Crewed Flight Test (demo)
    - PCM-1 awarded May 2015; Completed four milestones to date
    - PCM-2 awarded in December 2015; Completed four milestones to date
  - Official Dates For SpaceX:
    - April 2018: Flight to ISS without crew (Demo Mission 1)
    - August 2018: Flight to ISS with crew (Demo Mission 2)
    - PCM-1 awarded November 2015; Completed three milestones to date
    - PCM-2 awarded July 2016; Completed two milestones to date

Exploration Systems Recent Accomplishments

- Orion completed flight software release 28A
- Orion Crew Module and Crew Module Adapter initial power on (IPO) tests completed
- Key components delivered for European Service Module (ESM), including Reaction Control System Pods, Cold Plates, Water Tank, and Gas Tank Simulators
- Orion Initiated alternative designs for at-risk ESM components
- SLS Vertical Assembly Center (VAC) Welding Completed on LH2 Flight Tank
- SLS engine section structural qualification testing started
- SLS booster nozzle assemblies completed
- EGS Vehicle Assembly Building (VAB) fire protection and platform work completed
- EGS Core Stage Intertank Umbilical installed on Mobile Launcher
- EGS Spacecraft Command and Control Software (SCCS) progressing, with SCCS 4.0 system test 25% complete

EM-1 Integrated Mission Milestone Summary

Version Date: 11-7-2017



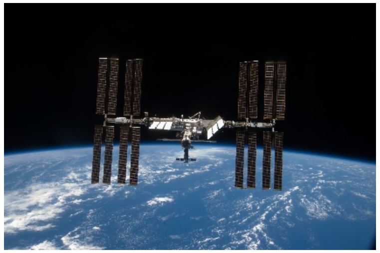
Improvements to Increase Confidence in Schedule Performance

Numerous changes have been implemented to increased confidence in enterprise schedule performance, including:

- Cross-Program Systems Integration (CSI)
  - Director CSI is now solely focused on Systems Engineering and Integration
  - Key personal assignments are in work to provide additional support
    - Support for increased volume of real time decision velocity
    - Evaluation of critical schedule items such as: green-run test, modal survey, and hardware transport, and intricate cross program deliverables with high interdependence such as: loads analysis, hardware verification, and software verification
    - Establish pre-planned contingency to address changes to schedule sequencing
- Program and Strategic Integration (PSI)
  - Improved schedule visibility and management
    - Established weekly ESD schedule review
  - Restructure of PSI schedule management organization to provide additional focus on Enterprise level schedule analysis
    - PSI Schedule Analysis Team (PSAT) established
    - Addition of key personnel to conduct Enterprise schedule analysis
    - Update to Enterprise schedule analysis tools to support Enterprise level assessments
  - Increased strategic evaluation of schedule risk and robustness measures
    - Improved integrated performance assessment process to enable trend analysis and early anticipation of issues/problems to enable timely decision making
- Corporate commitment and management attention at the highest levels
  - Senior executive reviews led by the Acting Administrator

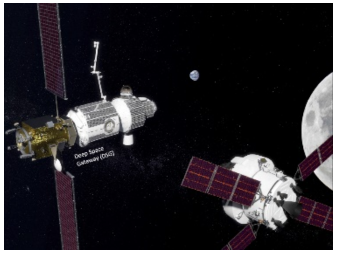
Advanced Exploration Systems Activities by Exploration Phase

Phase 0: Exploration Systems Testing on ISS



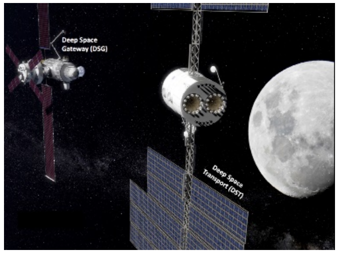
- Life Support Systems
- Spacecraft Fire Safety
- Radiation Safety
- Autonomous Mission Operations
- Logistics Reduction
- In-Space Manufacturing

Phase 1: Operating in the Lunar Vicinity



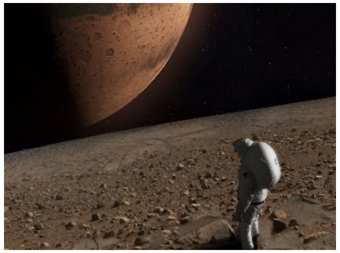
- Habitation
- Avionics, Software, & Communications
- Crew Module Systems
- Lander Technology
- EM-1 Secondary Payloads
- In-Situ Resource Utilization

Phase 2: Leaving the Earth-Moon System



- In-Space Power & Propulsion
- Deep Space Habitation Systems

Phases 3 & 4: Exploration in the Mars System



- Mars Robotic Precursors

Summary

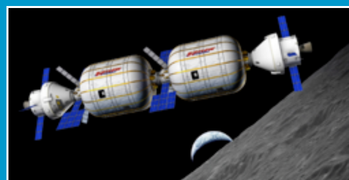
- AES is using the NextSTEP public-private partnerships to develop prototype cislunar habitats, habitation systems, and lunar lander capabilities
- AES is developing ISS flight experiments to demonstrate advanced life support and environmental monitoring systems that are relevant to future human spaceflight system such as those required for the Deep Space Gateway and Transport concepts.
- AES is developing five CubeSats for launch on EM-1 to address Strategic Knowledge Gaps including those critical to understanding lunar volatiles
- AES is partnering with STMD and SMD to develop three payloads for the Mars 2020 mission that will demonstrate enabling technologies and gain knowledge for human exploration.

NEXTSTEP HABITATION OVERVIEW

NextSTEP Phase 1: 2015-2016

Cislunar habitation concepts that leverage commercialization plans for LEO


LOCKHEED MARTIN


BIGELOW AEROSPACE


ORBITAL ATK


BOEING

FOUR SIGNIFICANTLY DIFFERENT CONCEPTS RECEIVED

Partners develop required deliverables, including concept descriptions with concept of operations, NextSTEP Phase 2 proposals, and statements of work.

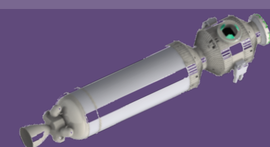
Initial discussions with international partners

NextSTEP Phase 2: 2016-2018

- Partners refine concepts and develop ground prototypes.
- NASA leads standards and common interfaces development.

FIVE GROUND PROTOTYPES BY 2018

ONE CONCEPT STUDY


NANORACKS

Define reference habitat architecture in preparation for Phase 3.

Phase 3: 2018+

- Partnership and Acquisition approach, leveraging domestic and international capabilities
- Development of deep space habitation capabilities
- Deliverables: flight unit(s)

Mars Oxygen ISRU Experiment (MOXIE)

- Ceramatec - the company that is supplying the Solid Oxide Electrolysis (SOXE) stacks – was bought by a Canadian company that plans to shut down Ceramatec's operations in Utah. JPL has received 11 flight SOXE stacks and does not expect this loss of a key supplier will affect MOXIE payload integration and testing.

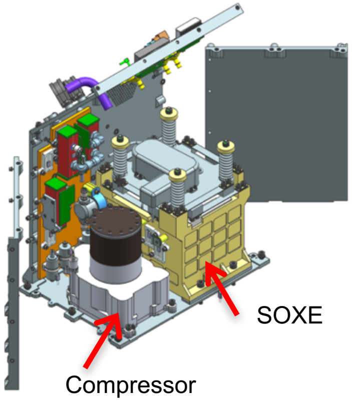
- The MOXIE scroll pump requires more power and its motor is operating at a higher temperature than predicted. A copper sleeve will be installed around the motor to conduct heat to the pump housing.

- Random current spikes have also been discovered during pump operation. The problem has been traced to friction in the pump bearings, which increases the pump power required to compress the Mars atmosphere. New bearings with greater radial play have been purchased.

- Completed over 450 hours of integrated testing with prototype SOXE stack, scroll pump, and SOXE drive electronics to validate experiment operation.

- The MOXIE electronics boards are still on the critical path. Engineering Model electronics have been fabricated and are being tested with flight software. The schedule margin for delivery of the flight hardware in October 2018 is currently 60 days.

MOXIE test bed integrated system testing



MOXIE configuration

- **BioSentinel (ARC):** Completed random vibration testing of spacecraft engineering model. Completed Phase 2 Safety Review. Radiation beam testing planned for October. Spacecraft integration will likely slip to December.

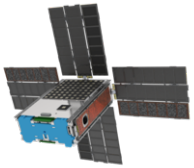
- **Lunar Flashlight (JPL):** Completed 100 mN thruster development testing. Space Dynamics Lab delivered Iris radio Engineering Development Unit to JPL.

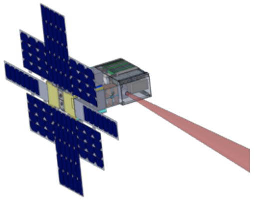
- **NEA Scout (MSFC)**: Completed vibration and thermal vacuum testing of Active Mass Translator. Deployed solar sail engineering model. Spacecraft integration will likely slip to January.

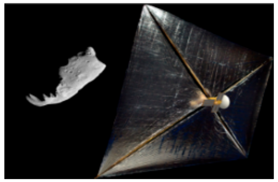
- **LunIR (Lockheed Martin)**: Procuring spacecraft bus from Tyvak. CDR completed in November.

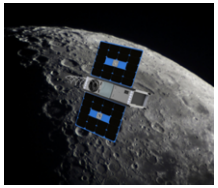
- **Lunar IceCube (Morehead State University)**: Completed spacecraft bus and IR spectrometer designs. Tested Busek ion thruster with iodine propellant. Upgrading 21-meter antenna and demonstrated Disruption Tolerant Networking to communicate with EM-1 CubeSats. Delta CDR will likely slip to December.

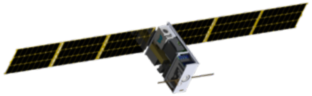
- **EM-1 Launch Delay:** CubeSats may be completed in Mid 2018 and stored for at least one year prior to launch. Planning activities to keep critical personnel and considering a change to the delivery dates.


BioSentinel


Lunar Flashlight


NEA Scout


LunIR


Lunar IceCube

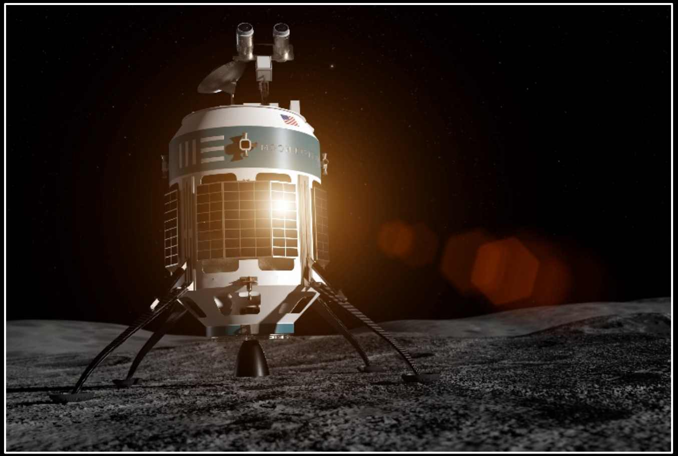
Lunar**CATALYST**

Lunar CArgo Transportation And Landing bY Soft Touchdown

In 2014, NASA competitively selected U.S. private-sector partners, based on likelihood of successfully fielding a commercially-viable lunar surface cargo transportation capability. Agreements renewed in 2017 for two more years.

Masten Space Systems

Moon Express

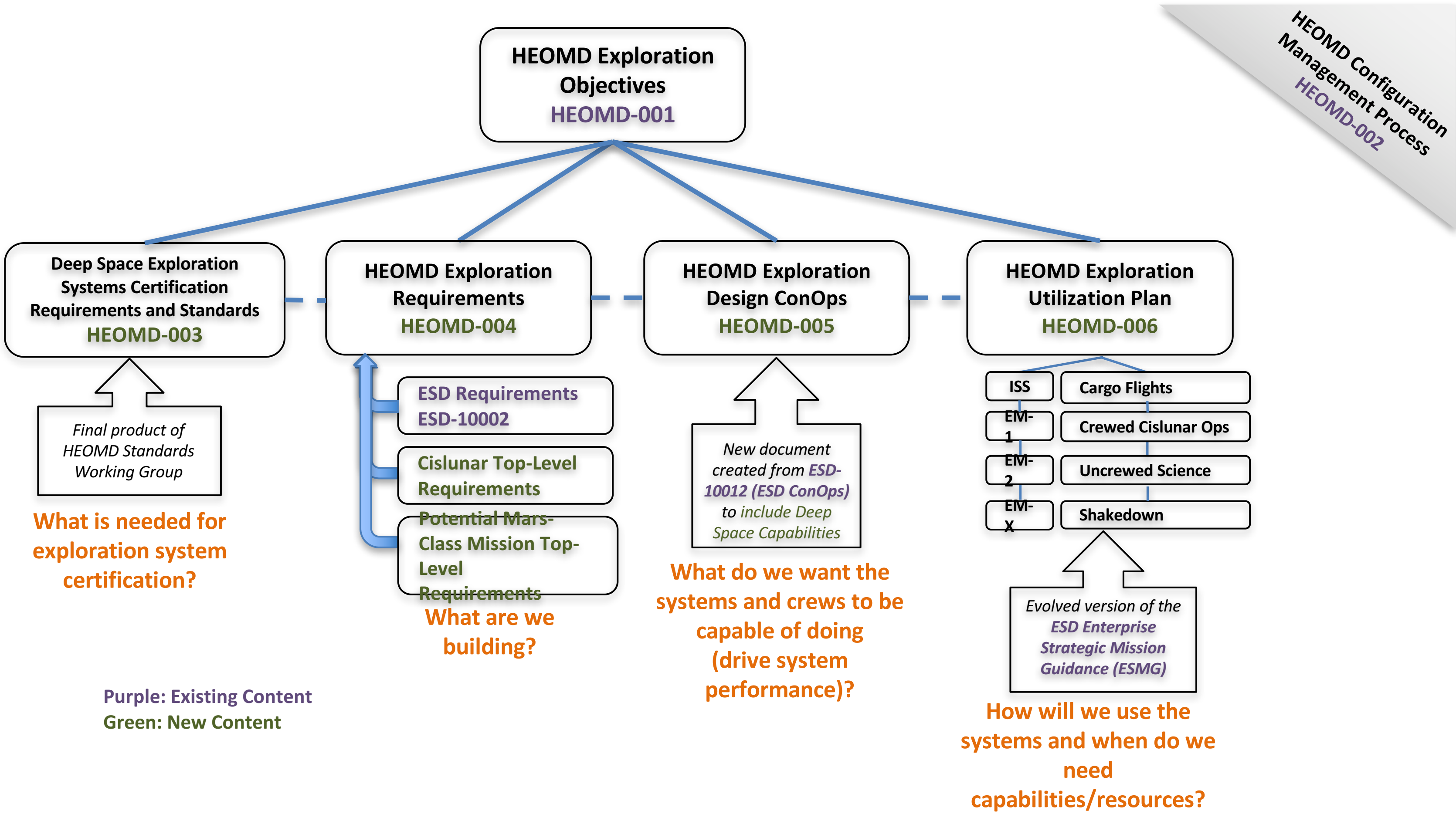


Astrobotic Technologies

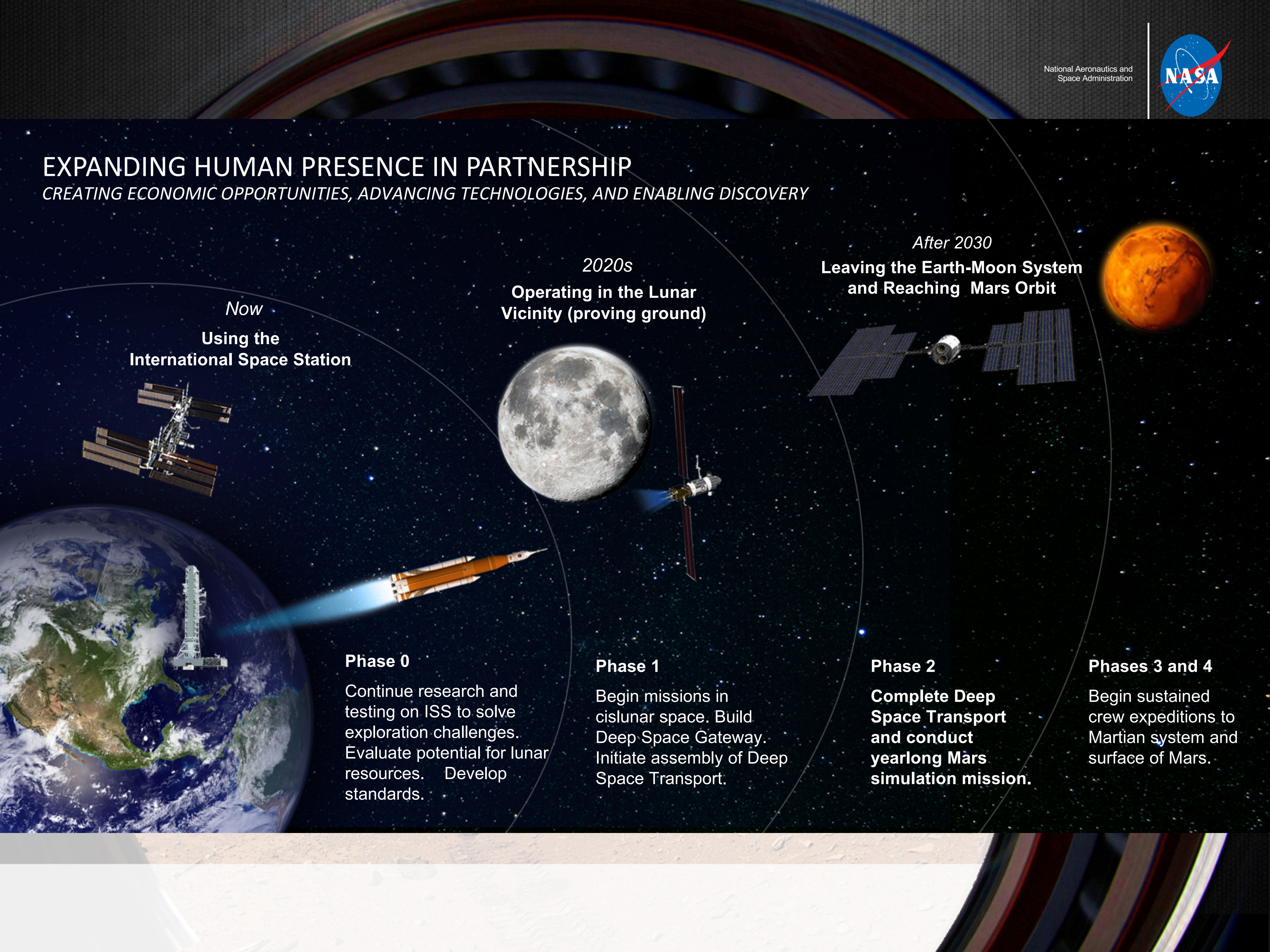
HELPING U.S. INUDSTRY PARTNERS TO

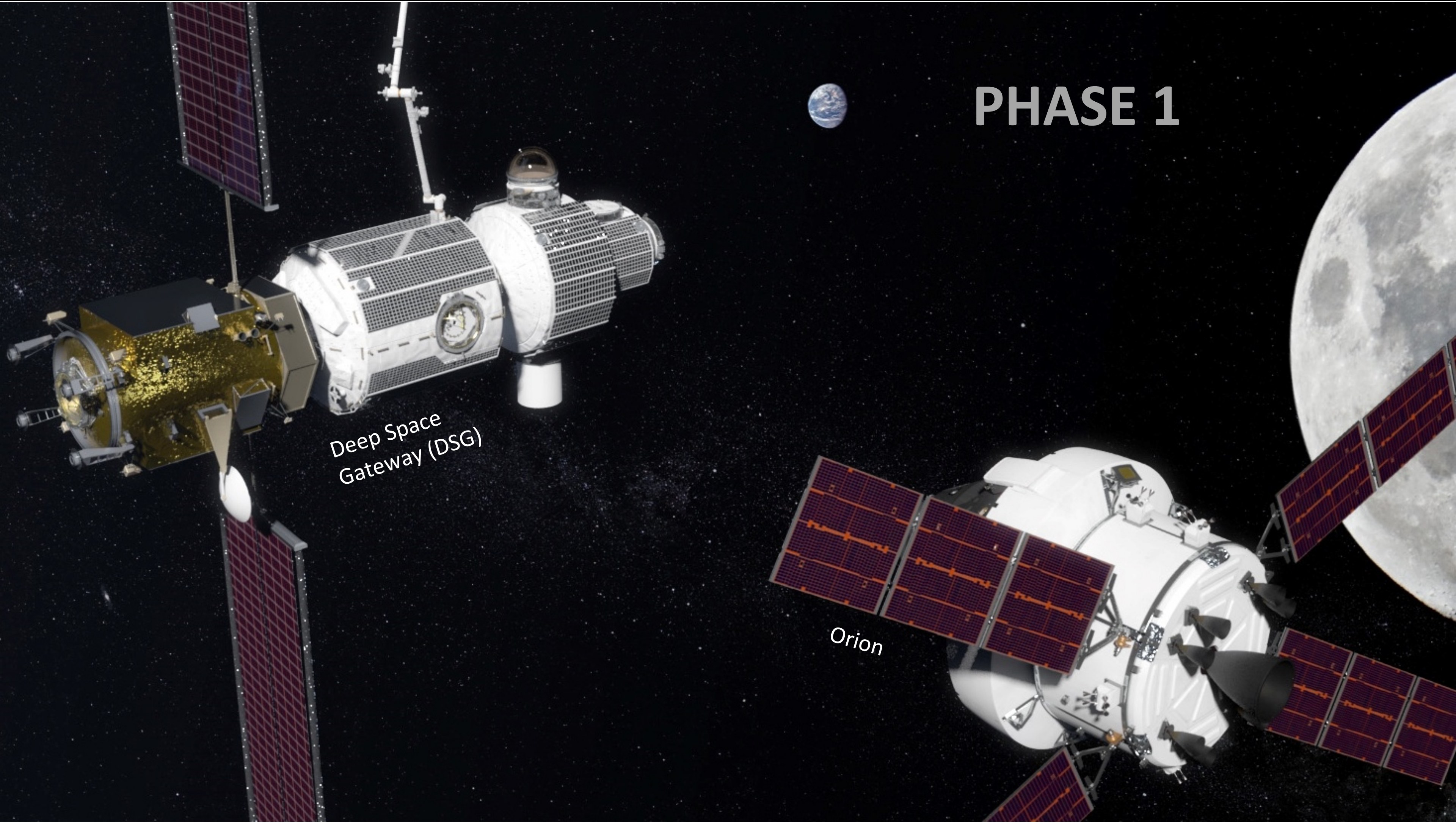
LOWER RISKS | CONDUCT TEST | ACCELERATE VEHICLE DEVELOPMENT TO LAUNCH

HEOMD Level 1 Documents



- **FISCAL REALISM:** Implementable in the near-term with the buying power of current budgets and in the longer term with budgets commensurate with economic growth;
- **SCIENTIFIC EXPLORATION:** Exploration enables science and science enables exploration; leveraging scientific expertise for human exploration of the solar system.
- **TECHNOLOGY PULL AND PUSH:** Application of high TRL technologies for near term missions, while focusing sustained investments on technologies and capabilities to address the challenges of future missions;
- **GRADUAL BUILD UP OF CAPABILITY:** Near-term mission opportunities with a defined cadence of compelling and integrated human and robotic missions, providing for an incremental buildup of capabilities for more complex missions over time;
- **ECONOMIC OPPORTUNITY:** Opportunities for U.S. commercial business to further enhance their experience and business base;
- **ARCHITECTURE OPENNESS AND RESILIENCE:** Resilient architecture featuring multi-use, evolvable space infrastructure, minimizing unique developments, with each mission leaving something behind to support subsequent missions;
- **GLOBAL COLLABORATION AND LEADERSHIP:** Substantial new international and commercial partnerships, leveraging current International Space Station partnerships and building new cooperative ventures for exploration; and
- **CONTINUITY OF HUMAN SPACEFLIGHT:** Uninterrupted expansion of human presence into the solar system by establishing a regular cadence of crewed missions to cis-lunar space during ISS lifetime.


National Aeronautics and Space Administration
NASA
EXPANDING HUMAN PRESENCE IN PARTNERSHIP
CREATING ECONOMIC OPPORTUNITIES, ADVANCING TECHNOLOGIES, AND ENABLING DISCOVERY
Now
Using the International Space Station
2020s
Operating in the Lunar Vicinity (proving ground)
After 2030
Leaving the Earth-Moon System and Reaching Mars Orbit
Phase 0
Continue research and testing on ISS to solve exploration challenges. Evaluate potential for lunar resources. Develop standards.
Phase 1
Begin missions in cislunar space. Build Deep Space Gateway. Initiate assembly of Deep Space Transport.
Phase 2
Complete Deep Space Transport and conduct yearlong Mars simulation mission.
Phases 3 and 4
Begin sustained crew expeditions to Martian system and surface of Mars.


PHASE 1
Deep Space
Gateway (DSG)
Orion

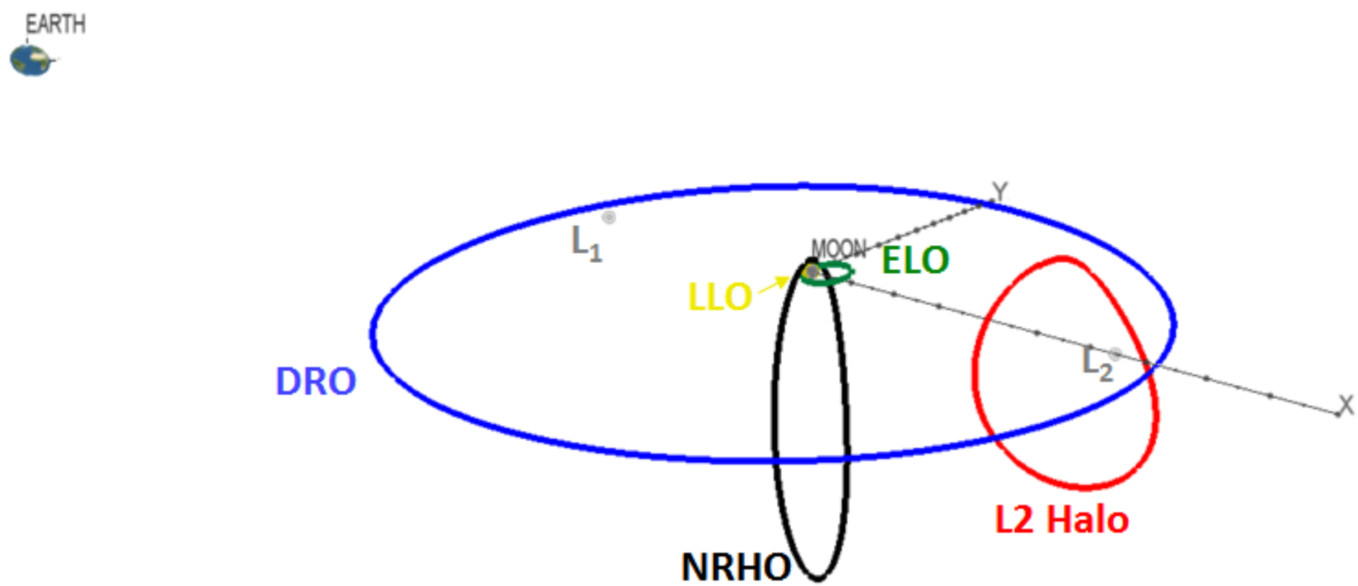
Why a Deep Space Gateway?

- **Develop propulsion and life support systems for Mars in preparation for a deep space transport. (The deep space transport will need more propulsion capability and life support systems which are more reliable than currently available.)**
- **The gateway allows operation in a more hostile deep space environment than the ISS, (Radiation levels are higher in the area where the deep space transport will be located, and servicing from earth will be more difficult.)**
- **The gateway can be moved to support different missions using its solar electric propulsion**
  - Assembly, Provisioning and Return of a Mars Transport
  - Safe haven for crew transport vehicles which can carry crews from Earth to Cis Lunar Space
  - Safe haven for transportation to and from the lunar surface
  - Potential servicing of deep space telescopes
  - Lunar surface science operations
  - Other deep space research and operations

Cislunar Space Utilization

Exploration Technology Validation	Utilization driven by technology development needs and roadmaps that feed forward
Commercial Capabilities	Assessment of commercial utilization interests
International Capabilities	International space agency utilization
Science and Research	Scientific expertise to cislunar space requirements, capabilities, concept of operations, and utilization from the larger Agency, international and academic communities.

DSG Orbits



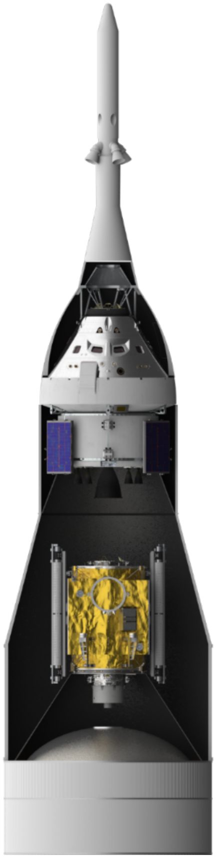
Orbit Type		Orbit Period	Lunar (or L-Point) Amplitude Range	Earth-Moon Orientation
Low Lunar Orbit (LLO)		~2 hrs	100 km	Any inclination
Elliptical Lunar Orbit (ELO)		~14 hrs	100 to 10,000 km	Equatorial
Near-Rectilinear Halo Orbit (NRHO)		6 to 8 days	2,000 to 75,000 km	Roughly Polar
Earth-Moon L_2 Halo		8 to 14 days	0 to 60,000 km (L_2)	Dependent on size
Distant Retrograde Orbit		~14 days	70,000 km	Equatorial

Power Propulsion Element

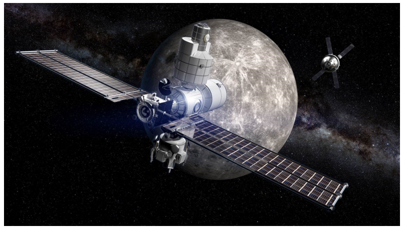
- **Advantages of solar electric propulsion in cislunar space**
  - **Storable fuel**
  - **Translation flexibility**
  - **Mass savings**
  - **Technology advancement for deeper space applications**

- **A power & propulsion element (PPE) would provide key functions for the gateway including**
  - **Transportation and controls for lunar orbital operations**
  - **Power to gateway elements**
  - **Communications**

- **PPE would launch co-manifested on SLS with Orion on EM-2**



Five study contracts announced 01Nov2018.
All are under contract.



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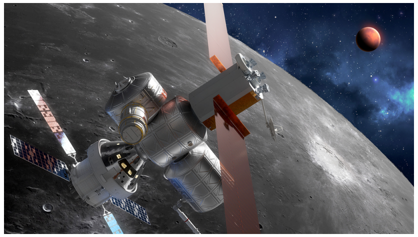
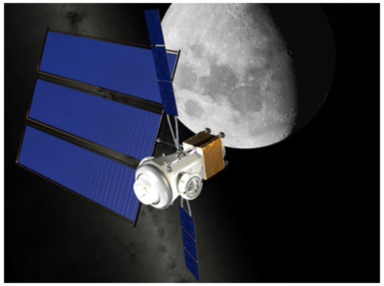


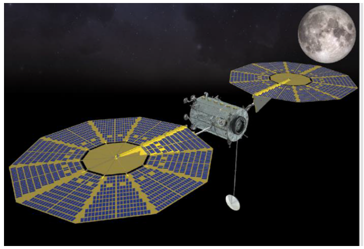
LOCKHEED MARTIN



SNC SIERRA NEVADA CORPORATION

AEROJET ROCKETDYNE

DRAPER



Orbital ATK

SSL

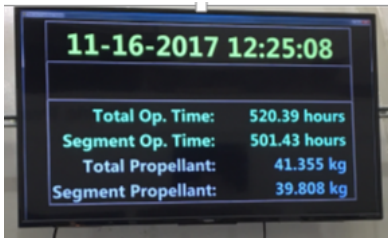
DSS Deployable Space Systems

DRAPER

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

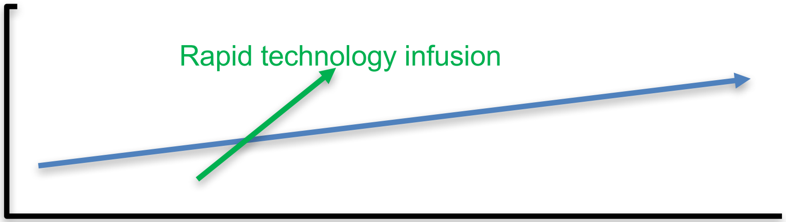
Technology Demonstration Unit (TDU) life testing at Glenn Research Center and JPL environment testing.

TDU-3 installed for testing



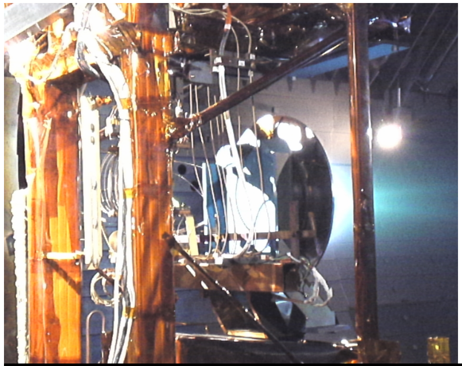
TDU-3 ongoing wear test

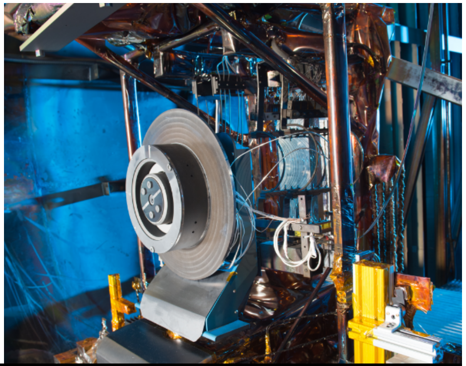
TDU power is 3x state-of-the-art with triple the lifetime



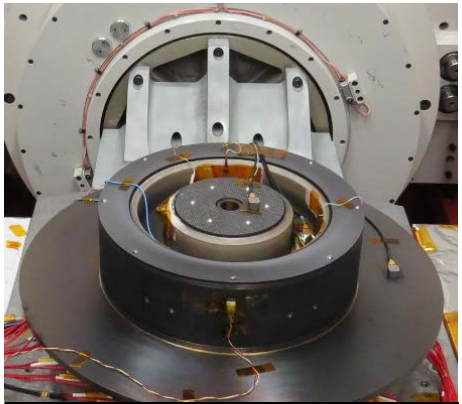
Pubic-private partnerships "could drastically reduce the time to market for these new EP technologies … from 10 to 15 years down to as little as 3–5 years."

Lev, et al., *New Space*, 2017

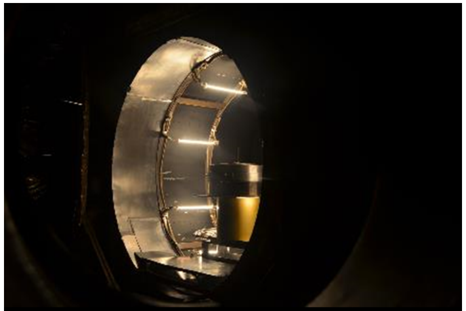




TDU-2 on the thrust stand



TDU-2 on the vibration table



TDU-2 mass model in TVAC shroud during pre-TVAC shakedown test.

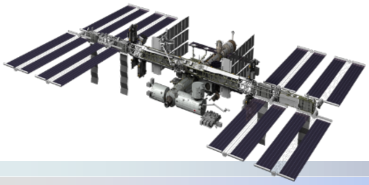
ISS Transition

- 2017 NASA Authorization Act requires a “ISS Transition Report”
  - 6 pages of questions and content to be included in the report
  - Requires input from CASIS, International Partners, scientific community and commercial industry

- Due to Congress on December 1, 2017

- Held an ISS Stakeholder Workshop in Washington, DC on August 9
  - Discussed policy and programmatic issues related to ISS and LEO
  - 4 breakout sessions
    - LEO Market
    - ISS Value Proposition
    - Public Private Partnerships
    - Access to Space for HSF

  - Discussion is captured at the following website:
    https://www.nasa.gov/content/international-space-station-stakeholder-workshop



Current State

- **US continuous human presence in LEO**
  - Continuous US human presence has been sustained over the past 16+ years
    - Commercial crew will add an additional crew member
    - US human spaceflight missions have been a part of American prominence and culture for over half a century

- **US Leadership in Human Space Flight**
  - Current ISS Inter-Government Agreements (IGA) have been in place for nearly 20 years and provide treaty-level agreements between US, Russia, Canada, Europe and Japan

- **Development of commercial markets in LEO**
  - Cargo and crew already supplied by private industry (~52% cost of current ISS)
  - Commercial crew and cargo support commercial launch industry
    - ~17% of US launch market goes to ISS (2017)
  - Research and tech dev demand development via National Lab/CASIS

Current State

- **Deep space - long duration Exploration**
  - Requirements for human health and performance research and technology/system demonstrations for habitation systems, and other exploration systems are currently planned to be completed by 2024/2025

- **Research and Development**
  - NASA sponsored research across life and physical sciences, human health, astrophysics, earth sciences, space science, many others
  - National Lab users have been greatly expanded into private industry and other government agencies via CASIS
    - Pharma, materials, manufacturing, human health, model organisms, consumer products
    - NASA continues to fund NL activities at $15M/year + transportation, crew time, power, data, etc. for no cost
    - Currently, private industry and OGA’s are probably not in a position to fully pay for capabilities (transportation, crew time, power, etc.) without ongoing NASA support

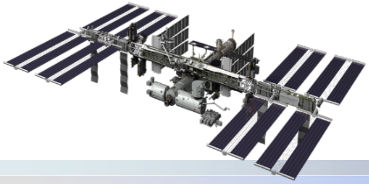
Cost to Enable

- **Primary cost driver for ISS is transportation**

- **Other drivers include**
  - Infrastructure and logistics needed to keep 6 crew members on-board year round
  - Complexity and scale of the on-orbit platform
  - Cost needed to carry international obligations

ISS Budget	Average FY18-22*
Total	$3.4B
O&M	$1.2B
Crew/cargo	$1.8B
Research	$0.4B
NL (within Research)	$15M

*based on FY18 President's Budget Request



Considerations

- Foreign Policy Considerations
  - US leadership in HSF
  - Other LEO space stations

- Future of the National Lab
  - Role of the government in fostering R&D across private industry and non-NASA government agencies

- Re-use of on-orbit ISS elements
  - Many elements will have considerable structural life after 2028
  - Some systems, including the solar arrays, will need to be replace by the end of the 2020s in order to maintain the current configuration
  - Maintenance levels less than originally anticipated
  - Value of the nation’s investment is considerable

Element	Year Launched	+30 years
FGB/Node 1	1998	2028
US Lab	2001	2031
Node 2	2007	2037
Columbus/JEM	2008	2038
Node 3/Cupola	2010	2040
Truss segments	2000-2009	2030-2039

Considerations

- Long-term NASA requirements for LEO research and utilization
  - NASA is currently assessing its LEO long term requirements and utilization needs

- Scope of public-private partnership models
  - There is a large range of private partnership arrangements that could be considered
    - Proper role of the government vs. private industry would need to be explored
    - International Partner agreements
    - Ability for private industry to do business outside of government constraints
    - Scope of government needs for LEO in the long term

HEO Committee Observations

- The committee observed continued technical progress on HEO programs since our last meeting, and continues to be impressed by the amount of work being managed by the directorate team.

- NASA has a lot of work ahead to accomplish the goals being set out for deep space exploration, while at the same time developing commercial crew capabilities and managing the International Space Station. Increased emphasis on organizational efficiency, stable requirements and decision velocity will be critical to meet the current schedules.

- The implementation of the National Space Council provides an excellent opportunity for NASA to air and gain assistance in resolving issues which affect the broader space community such as the dwindling supplier base for some critical space components.

- NASA plans to take a different approach to human rating of a deep space gateway than that used for human rating of the Orion deep space transport, since a human rated spacecraft would be present whenever humans were present to tend the gateway. Documentation of the approach used to certify that this human tended spacecraft is safe for humans would be useful for future programs.

- The phased approach that NASA has developed for exploration that included work in LEO, a Cislunar proving ground, and other phases in deep space supports NASA strategic plan objectives and was comprehensive, yet flexible. It should continue to be used as the guiding framework for our Nation's space exploration program to expand human presence across our solar system, even if the focus in Cislunar space moves to the lunar surface.

Finding – NASA Human Exploration Plans

Proposed NASA Advisory Council Finding
NASA Human Exploration Strategy

Name of Committee:	Human Exploration and Operations Committee
Chair of Committee:	Mr. Ken Bowersox
Date of Public Deliberation:	November 27 and 28 (HEO Advisory Committee)
Short Title of Finding:	NASA Human Exploration Plans

NASA's current phased approach to exploration which includes ISS for the Earth dependent phase, Cislunar space for the proving ground and goals beyond Cislunar for the Earth independent phases provide a useful framework for future exploration efforts. An important element in the phased approach is that human exploration efforts in the Cislunar proving ground contribute to future exploration efforts beyond Cislunar space, even if the focus of Cislunar activity shifts to the lunar surface.

Proposed NAC Recommendation December, 2017

TITLE: Interactive Link Between NAC and National Space Council

Recommendation: The Council recommends that NASA work with the National Space Council staff to establish an interactive link between the NASA Advisory Council and the National Space Council.

Major reasons for proposing the recommendation: The implementation of the National Space Council provides an excellent opportunity for NASA to bring up problems and gain assistance in resolving issues which affect the broader space community. such as the dwindling supplier base for some critical space components. The NASA Advisory Council has tremendous insight into NASA, and could provide valuable input to the National Space Council staff on significant issues which have not reached the urgency level required for discussion at formal Space Council meetings.

Consequences of no action on the proposed recommendation: NASA will lose opportunities to gain the help of The National Space Council on issues that may not yet have reached the urgency level required to be brought up and discussed by Space Council members..

HEO Committee Concerns

- Budget uncertainty and lack of flexibility in use of funds continues, and now has greater potential for program disruption as SLS and Orion get closer to launch.
- Bureaucratic processes that NASA imposes on itself do not always add value to balance their load on the organization and are a threat to accomplishment of NASA's exploration mission.
- The number and intensity of current reviews of the HEO programs are not helpful and use too many precious resources.
- Low SLS and Orion Launch rate pose future risks for proficiency of the operations team and reduce program resilience in the event of mission failure
- Shifting priorities may result in the reduction of government funding for the ISS before a viable U.S. commercial follow-on capability is established. This capability is critical to allow NASA continued access to low Earth orbit for research, deep space exploration system testing, and other applications that may arise.

Special Topics at Future HEO Committee Meetings

- Future Special Topics:
  - International Participation in future human exploration
  - ISS after 2024 and ISS commercialization efforts ***
  - Launch readiness process for commercial crew
  - Systems Engineering and Integration for Exploration Systems
  - Deep space telescopes and possible servicing missions
  - Planetary Protection
  - Program decision making approach and independent technical authorities
  - Exploration EVA Capability
  - HEO External Review Summary

*** Discussed at this meeting – November 2017 www.nasa.gov